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Prevalence and origin of birefringence in 48 garnets from the pyrope-almandine-grossularite-spessartine quaternary

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ABSTRACT

Forty garnets are anisotropic among 48 in a suite spanning the quaternary system $Mg_3Al_2Si_3O_{12}$-$Fe_3Al_2Si_3O_{12}$-$Ca_3Al_2Si_3O_{12}$-$Mn_3Al_2Si_3O_{12}$ (Py-Al-Gr-Sp). The eight isotropic specimens are too thin (<0.4 mm) for detection of weak anisotropy. Birefringence (δ) in the remaining 40 garnets is low (δ = 0.0001 to 0.0006) and undulatory in appearance, suggesting that most optical anomalies in quaternary garnets, including the pyrope-almandine-spessartine ternary, originate through residual strain. Multiple or alternate origins are not precluded for the few samples with nearly uniform retardation or unusual sector twinning. An inverse correlation exists between degree of birefringence and stresses encountered during tectonic deformation. That is, mantle garnets from kimberlites (e.g., $Py_{37}Al_{36}Gr_{27}$) have the highest δ values. As geologic setting is difficult to separate from composition, the inverse trend suggests that birefringence arises partially from internal factors. We propose that the mismatch in size between Ca^{2+} and Mg^{2+} exacerbates retention of residual strain. Short-range ordering is not entirely ruled out, but clustering has only been inferred for synthetics in the middle of the Py-Gr binary, a composition range unknown for natural samples, and domains are precluded in the natural samples by the recent X-ray studies of samples from similar localities.